

DIGESTIBILITY AND NET ENERGY STUDIES WITH
BIRD-RESISTANT SORGHUM GRAIN DIETS FED TO STEERS

By

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DEDICATION

To my wife, Joann, for her understanding and encouragement
during this period of academic endeavor.

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Abstract of Dissertation Presented to the
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DIGESTIBILITY AND NET ENERGY STUDIES WITH
BIRD-RESISTANT SORGHUM GRAIN DIETS FED TO STEERS

By

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Two experiments were conducted on utilization of nutrients in sorghum grain diets with steers. In one of the experiments the digestibility of nutrients was determined with six crossbred, Hereford X Angus steers using a 3 X 3 crossover Latin square design trial in which dietary treatments were bird-resistant sorghum grain diets, with and without added bentonite or soft phosphate. Addition of 2% bentonite or 1% soft phosphate to the diet had no significant effect on digestion of dry matter, organic matter, fiber, nitrogen-free-extract or total digestible nutrients. Digestion of nitrogen and apparent ash absorption were decreased ($P < .01$) when 2% bentonite was added. Addition of 1% soft phosphate decreased ether extract digestion ($P < .05$). Digestion or urinary excretion of dietary tannins was not affected by the additions of bentonite or soft phosphate to the diets.

The second experiment investigated the utilization of energy in sorghum grain and corn diets by steers. This involved metabolism and feedlot phases. In the metabolism phase three Angus steers were randomly assigned to a 3 X 3 Latin square trial to determine the

metabolizable energy and digestibility of other nutrients of corn, non-bird-resistant and bird-resistant sorghum grain diets. The corn diet contained more digestible dry matter, organic matter, nitrogen, nitrogen-free-extract, energy, metabolizable energy and total digestible nutrients than either of the two types of sorghum grain diets. The non-bird-resistant sorghum grain diet contained slightly more digestible dietary nutrients than the bird-resistant sorghum grain diet.

The feedlot trial involved 48 steers equally assigned to six treatment groups. They were fed the diets described above at limited and ad libitum levels of intake. The corn diet produced more live weight gain on less feed than either sorghum grain diet. Steers fed the non-bird-resistant sorghum grain diet gained slightly faster and consumed less dry matter than those fed the bird-resistant sorghum grain diets.

Using data from both the metabolism and feedlot trials the net energy for maintenance values of the corn, non-bird-resistant and bird-resistant sorghum grain diets was 1.67, 1.41 and 1.35 Mcal per kg of diet, respectively.

Metabolizable energy calculated by multiplying the NRC factor times the total digestible nutrients gave values within 5% of those actually determined. Blaxter's metabolizable energy system and the net energy for maintenance and gain values in tables in the NRC Bulletin on Nutrient Requirements of Beef Cattle were compared in regard to predicting live weight gains. Both systems gave values for predicted gains that were within 0.1 kg per day of the actual values obtained by the steers fed the corn diet ad libitum. The NRC system was closer to the actual gain values for the non-bird-resistant sorghum grain diet while values by Blaxter's system were closer with

the bird-resistant sorghum grain diet. The NRC system was consistently closer to the actual values from the feedlot data with all limited-fed dietary groups than Blaxter's system. From an overall view of the data the NRC system should probably be considered the better of the two systems.

INTRODUCTION

It should greatly aid the cattle feedlot industry in Florida to succeed if new high quality energy feeds were produced in the state. Sorghum grain is a prospective high energy feed. Several problems such as bird damage and variability in feeding value of the sorghum grains have detracted from their widespread acceptance in comparison to corn. Plant geneticists have worked for many years to develop high yielding types of sorghum grain that are bird-resistant. At the present time several bird-resistant types are being grown in the United States. These new types of sorghum grains appear to be suited to Florida since they have produced as much or more tonnage of grain per acre during dry years than corn or non-bird-resistant types.

Variability in feeding quality is characteristic of sorghum grain and has been shown to exist widely throughout the United States (Hale et al., 1968, from Arizona; McGinty and Riggs, 1968, from Texas; and Bertrand and Lutrick, 1971, from Florida). Variability may range in digestibility of the amino acids from 60 to 80% as reported by Henderson and Breuer (1969). Rate of gain data has shown the bird-resistant types to be inferior to the non-bird-resistant sorghum grain when fed to cattle (Anonymous, 1969; and Bertrand and Lutrick, 1971). In order that Florida-grown sorghum grains be fed most efficiently, the feeding values of different genetic types need to be determined.

The cattle feeder of Florida should benefit most if the feeding quality of locally produced sorghum grains was determined with the type of cattle and conditions that exist in Florida. The net energy for

maintenance and net energy for gain values of Florida-produced sorghum grains especially need to be evaluated. Some livestock producers question if the types of sorghum grains grown in the state have feeding values comparable to those used as guidelines in the Bulletin on Nutrient Requirements of Beef Cattle (NRC, 1970). Since most feeders are familiar with total digestible nutrients (TDN) rather than net energy, both TDN and net energy values need to be obtained so the cattle feeders can compare them.

Metabolizable energy has been used to predict gains in growing finishing cattle by Blaxter (1962). Since it is easier to obtain metabolizable energy values for a ration than net energy values, work needs to be done to evaluate the two systems as to their accuracy at predicting gains for cattle.

The present investigation was carried out to evaluate sorghum grain diets in regard to digestible nutrients, feedlot performance, net energy for maintenance and weight gains. Comparisons of the net energy system versus the Blaxter metabolizable energy system for predicting gains were carried out. The metabolizable energy value was also compared to a calculated metabolizable energy value based on the total digestible nutrients of the diet, using the National Research Council factor (NRC, 1970).

LITERATURE REVIEW

Sorghum grain has been fed to livestock and poultry with variable results and generally with less success than corn diets. The present review primarily covers that portion of the literature that pertains to the nutritive value of sorghum grains for ruminant animals.

Feeding Value of Sorghum Grain

Determinations of the nutrient availability of sorghum grain has demonstrated that many factors may affect its quality as a feed for ruminants. One such factor is the variety. There are numerous varieties of sorghum grain and frequently this information is not reported in experimental feeding trials. Cardon (1964) reported that sorghum grain varieties may vary in protein from 8.4 to 11.9% and starch from 67.9 to 76.5%. Eng et al. (1965) observed protein values ranging from 9.3 to 14.0% with digestibilities of 62.1 to 78.6% when several sorghum grains were tested. McGinty and Riggs (1968) reported protein digestibility to range from 23.4 to 54.4% with eight different varieties of Texas sorghum grain. Protein digestibility data have been associated with location by variety interaction (Driedger and Riggs, 1972) and amount of nitrogen fertilization (Eng et al., 1965). Henderson and Breuer (1969) reported that the digestibility of the individual amino acids of sorghum grain may vary from 60 to 80%. Dry matter digestibility varied among 61 varieties of sorghum grain from 43.7 to 137.0% when corn was used as a standard (Samford et al., 1970a). The ash fraction varies in concentration significantly as reported by Furr and Sherrod (1968). These workers reported an average content of calcium,

phosphorus, magnesium, potassium, sulfur, copper, iron, manganese, zinc and molybdenum in 132 train loads of sorghum grain to be 0.06%, 0.44%, 0.15%, 0.48%, 0.09%, 5.7 ppm, 52.8 ppm, 21.2 ppm, 26.4 ppm, and 0.6 ppm, respectively.

Investigators have classified sorghum grain according to the sorghum endosperm type. Sherrod, Albin and Furr (1969) classified sorghum grain into regular and waxy types. Approximately 100% of the starch contained in the waxy type is amylopectin while the starch of the regular type is 75% amylopectin and 25% amylose. These authors reported that waxy sorghum grain contains more net energy for maintenance and production than does the regular type of sorghum grain. When sheep were fed waxy or regular types of sorghum grain, Sherrod and Furr (1970) reported no differences in their digestibilities. This supported results reported by Nishimuta, Sherrod and Furr (1969) in which there was no significant difference in the digestibility of the regular or waxy types of grain sorghum when fed to sheep. Samford et al. (1970b) classified sorghum grain endosperm types into floury, waxy, normal, and corneous, depending on the sorghum's starch granules, and reported carbohydrate digestibility percentages of 80.1, 75.0, 68.1, and 48.4, respectively. The normal type in this trial is similar to the regular type in the above experiments by Sherrod et al. (1969).

A broad category of sorghum grain classification is bird-resistant and non-bird-resistant types. Rate of gain and feed efficiency of the bird-resistant type was observed to be lower with steers than that of the non-bird-resistant type (Bertrand and Lutrick, 1971). Withers et al. (1969) and Pund (1970) reported that silage from non-bird-resistant sorghum is utilized more efficiently than silage from the bird-resistant type. When starch digestibility was compared in the two types of sorghum

grain the starch in the non-bird-resistant type was more available than in the bird-resistant type (Hinders and Eng, 1971). An extensive study was conducted by McGinty, Riggs and Kunkel (1969) to determine the digestibility of bird-resistant and non-bird-resistant sorghum grain, in vitro. The non-bird-resistant type supported greater bacterial activity. The pericarp and endosperms of the two varieties were separated and placed in separate fermentation tubes. The endosperms of the two varieties supported in vitro gas production equally. But the pericarps of the bird-resistant type supported significantly less gas production when mixed with either endosperm. These workers concluded that the tannin contained in the seed coat of the bird-resistant sorghum grain was likely the cause of the decreased digestion.

To improve the feeding value of sorghum grain investigators have tried various processing techniques. One of the most popular processing techniques is steam flaking. Kuhlman et al. (1968) reported significant increases in weight gains and feed efficiency of cattle fed steam flaked compared to dry rolled sorghum grain. Steam flaking and pressure cooking was shown to result in greater digestibility when compared to dry rolling, steam cut, water soaked cut, and fine ground sorghum grain (Husted et al., 1968). Holmes, Drennan and Garrett (1970) reported that when pressure was increased from 0 to 3.5 kg per cm² during cooking that there was no difference in the digestibility of starch or the rate of gain for ruminants. Schuh, Hale and Theurer (1971) also reported that pressure cooking gave similar results in comparison to steam processing or flaking when fed to dairy calves.

Another popular method for processing sorghum grain is reconstituting the grain with water and storing it in air-tight containers. Neuhaus and

Totusek (1971) reported that the moisture level for the greatest digestibility of sorghum grain is 36%. Feedlot trials have shown that cattle fed high moisture sorghum grain tend to consume less dry matter daily but utilize it more efficiently than cattle fed air dried grain (Brethour and Duitsman, 1961; Newsom et al., 1968; Riggs and McGinty, 1970; and Kiesling, McCroskey and Wagner, 1971). Buchanan-Smith, Totusek and Tillman (1968) and Eudaly and Riggs (1969) reported that dry matter digestibility of steam-rolled sorghum grain is not significantly greater than dry matter digestibility for reconstituted grain. McNeill, Potter and Riggs (1971) reported that starch and protein digestion was increased in sorghum grain by reconstituting compared to steam flaking (Potter, McNeill and Riggs, 1971). In vitro digestibility of reconstituted sorghum grain was increased when acetic acid, metaphosphoric acid or sodium hydride was added to the water used for reconstitution (Lane, Leighton and Bade, 1972).

One of the newest methods for processing sorghum grain is popping. Popping results in decreased feed intake as stated by Ellis and Carpenter (1966) and Riggs et al. (1970). These authors reported that although the feed intake was decreased the efficiency of utilization was increased. In a rate of gain trial with feedlot cattle there was no statistical difference between diets of popped, flaked or cracked sorghum grain (Durham, Ellis and Cude, 1967).

Sorghum grain has been compared with many other concentrates as a livestock feed. Tommeroik and Waldern (1969) reported no differences in milk production when cows were fed either wheat, corn, barley, oats, or sorghum grain. Similar results were obtained by Franks et al. (1972) when no differences in rate of gain or feed efficiency with feedlot cattle

occurred upon comparing barley, oats, corn or sorghum grain. Sorghum grain is considered to be quite similar in feeding value for dairy cows (Brown et al., 1966) and fattening steers (Ralston et al., 1963, and Hale et al., 1966) when compared to barley. Garrett, Lofgreen and Meyers (1964) and Garrett (1965) reported no significant differences in the net energy of barley or sorghum grain when fed to feedlot cattle. Dry matter has been reported to be more digestible in barley than in sorghum grain (Saba et al., 1964). The starch of barley has been observed to be utilized more efficiently than the starch in sorghum grain (Cadena et al., 1962, and Osman et al., 1970). Taylor et al. (1960) obtained increased rate of gain and feed utilization when cattle were fed barley compared to sorghum grain. Sorghum grain was superior to barley in both digestibility and feedlot performance of cattle according to Keating et al. (1965). Brown et al. (1970) demonstrated that sorghum grain was superior to barley when milk fat production of dairy cows was the test criterion.

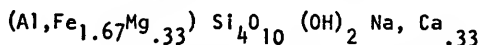
Variability in feeding value of sorghum grain became apparent when research comparing sorghum and corn was reviewed. Sorghum grain diets were reported equal to corn diets in digestibility, energy and nitrogen retention for cattle (Brown, Tillman and Totusek, 1968). Hall et al. (1968) state that there is no reason for cattle feeders to discriminate against sorghum grain as an energy source when it is fed with balanced minerals, vitamins and protein. These authors based their statement on their research showing corn and sorghum grain equal in net energy. However, they pointed out that variation among sorghum types could affect its feeding value. Fox et al. (1970) reported more net energy in corn grain and silage than in either sorghum grain or silage. Gross energy, digestibility or protein, ether extract, nitrogen-free-extract, and dry matter were reported higher for

corn than sorghum grain (McCollough et al., 1972). In feedlot trials Bertrand, Dunavin and Lutrick (1970) and McCollough et al. (1972) have shown corn to be slightly superior in producing increased rate of gain than sorghum grain. These authors reported that feed efficiency was better with corn. Newland, Kosterman and Fox (1970) reported corn rations produced gains significantly faster than bird-resistant sorghum grain rations.

Bentonite

Bentonite is a clay consisting primarily of montmorillonite.

Montmorillonite has the approximate chemical formula:



Approximately 10% of bentonite consists of small fragments of other minerals, the most abundant being feldspar (Martin, 1967).

In the wine industry, bentonite is used to precipitate tannins (Deis and Sanchez, 1964). Work by Filippov and Valuiko (1970) and Valuiko and Ivanyutina (1970) obtained similar results demonstrating that bentonite precipitated tannins. Bentonite has been used as an additive to livestock and poultry feeds in the United States for several years, generally because of its binding property for pelleted feeds. Addition of bentonite to diets may cause problems with animals under certain conditions. Vitamin A deficiency was produced with chickens when Briggs and Fox (1956) fed 2 or 3% of sodium or calcium bentonite. The vitamin A source used in their study was unstabilized and the deficiency probably would not have occurred if stabilized vitamin A had been fed. Bentonite has been used to isolate vitamin B₁₂ from biological samples followed by elution of the vitamin prior to analysis (Popova, 1962). It is believed that the capacity of bentonite to absorb and exchange many

substances may at times decrease excesses of toxic materials, but at times may decrease availability of nutrients that are already at low concentrations.

Bentonite has been fed to ruminants without detrimental effects (Erwin et al., 1957; Hillis, 1968; and Mendel, 1971). In the dairy industry bentonite is added to high energy rations to counteract the decrease in the milk fat percentage that characteristically occurs with such diets (Bringe and Schultz, 1969; Rindsig, Schultz and Shook, 1969; Rindsig and Schultz, 1970). Rindsig and Schultz (1970) found that the addition of 5 or 10% bentonite to high grain diets decreased significantly dry matter and nitrogen digestibility by lactating dairy cows. In work done with sheep fed a high roughage ration the addition of 2 to 8% bentonite did not significantly decrease dry matter digestibility; however, at 2% of the diet it slightly increased nitrogen retention (Martin, Clifford and Tillman, 1969).

When bentonite was added to feedlot type diets that contain urea inconsistent results have been obtained. Vetter, Gay and Ransom (1967) found that 150 g of bentonite consumed per day by steers fed feedlot type diets resulted in an increase in weight gain and feed consumption. However, subsequent studies (Vetter et al., 1968; Perry et al., 1968) indicated that the bentonite was without effect. Using feedlot diets containing urea, data was obtained that demonstrated that the addition of 2% bentonite increased daily gain 86 grams (Anonymous, 1967). Burkitt (1969) added 2% bentonite in pellets fed cattle and obtained 168 grams of greater daily gain. As such studies with bentonite are limited and have yielded inconsistent results, it is evident that there are factors that are not well understood about its use in feeds for ruminants.

Soft Phosphate

Soft phosphate is a colloidal clay that is produced during the mining of rock phosphate. In the livestock industry research has been conducted to determine the biological availability of phosphorus from soft phosphate for ruminants. Anderson, Cheng and Burroughs (1956) and Long et al. (1956) reported that the availability of phosphorus from soft phosphate was lower than that from dicalcium phosphate or steamed bone meal. Using the isotope dilution method Lofgreen (1960) determined the true digestibility of phosphorus from soft phosphate to be 14% compared to 40, 46 and 33% in dicalcium phosphate, bone meal, and calcium phytate, respectively. Wise, Wentworth and Smith (1961), working with growing calves and measuring feed intake, weight gain and bone concentration of phosphorus as criteria, rated the availability of phosphorus from soft phosphate to be below that of defluorinated rock phosphate, Curacao Island phosphate and dicalcium phosphate. Ammerman et al. (1957) compared soft phosphate, bone meal, Curacao Island phosphate, two calcined defluorinated phosphates and two dicalcium phosphates in rations fed steers and observed that phosphorus retention and blood phosphorus levels were equivalent in the treatment groups. When lambs were fed phosphorus from some of these sources by the investigators, calcium phosphate and Curacao Island phosphate were well utilized, but soft phosphate and a calcined defluorinated phosphate were poorly utilized.

The high fluorine content of soft phosphate is another factor that limits its utilization in livestock feeds. Hobbs et al. (1954) reported that when the diet of growing steers exceeds 200 ppm of fluorine the animals have decreased feed consumption, weight gains,

stiffness and impaired vision. Ammerman et al. (1957) and Ammerman et al. (1964) observed soft phosphate to contain 1.44% fluorine. Soft phosphate containing this level of fluorine added at 1% concentration to a diet would provide 134 ppm of fluorine in the feed. In view of data reported by Hobbs et al. (1954), Ammerman et al. (1957), and Ammerman et al. (1964) soft phosphate should not be incorporated in the diet of growing-fattening animals at a level greater than 1%.

California Net Energy System

The California net energy system was developed by G. F. Lofgreen, W. N. Garrett, and others. It is the culmination of the ideas and work of many investigators.

Disagreement existed among researchers interested in the efficiency of energy utilization at and above maintenance. Klieber (1961) postulated that the energy utilization for maintenance is greater than it is for production. Blaxter (1956) contended that energy utilization is best from maintenance to an intermediate level of gain. Differences such as these were difficult to resolve due to the cost of classical calorimetric balance trials. Lofgreen and co-workers attempted to develop a new system to evaluate energy utilization.

Lofgreen and Otagaki (1960) introduced the concept of comparative slaughter technique for determination of energy retention. This method required the determination of specific gravity of the carcass of representative animals at the beginning of the feeding trial and those in the feedlot at the termination of the trial. From specific gravity values fat and protein percentages in the carcass can be calculated by formulas developed by Reid, Wellington and Dunn (1955), and percent body water as recommended by Kraybill, Bitter and Hankins (1952). Energy

contained in the body fat and protein was calculated by multiplying 9367 kcal times kg of fat (Blaxter and Rook, 1953) and 5686 kcal times kg of protein (Garrett, 1958). Using this method an investigator can calculate the total energy contained in a carcass. Lofgreen, Hull and Otagaki (1962) derived a formula to calculate empty body weight from warm carcass weight, so that energy retention could be related to empty body weight gain.

Now that the energy retained by the animal could be calculated, Lofgreen, Bath and Strong (1963) introduced a method to identify net energy in the feed into net energy for maintenance and net energy for production.

To determine net energy for maintenance and production, metabolizable energy must first be determined. In the California net energy system metabolizable energy needs to be determined as usual by subtracting energy contained in the feces, urine and methane from the gross energy intake. The amount of methane produced by an animal fed any diet can be calculated from the digestible nitrogen-free-extract portion (Bratzler and Forbes, 1940). Energy in the methane is determined by multiplying 213 kcal times the moles of methane produced (Morrison and Boyd, 1970).

Net energy for maintenance is determined from metabolizable energy in the feed. Garrett, Lofgreen and Myer (1964) demonstrated that the total heat production for steers could be calculated by the following formula:

$$\text{Log HP} = 1.9073 + 0.00148 \text{ ME kcal/W}^{.75\text{kg}}$$

HP is the heat produced and ME is the metabolizable energy. Lofgreen and Garrett (1968) stated that net energy for maintenance is equal to heat produced by the animal at zero energy intake. The heat produced at zero energy intake is 77 kcal times the metabolic body weight of the animal.

This value can be used as one point on a graph. A second point for heat production on the graph can be calculated by inserting the metabolizable energy value determined directly on the feed, in the above formula. Next the metabolizable energy equal to the heat production can be read directly from the graph. Then the grams of feed required to equal heat produced can be calculated by dividing the heat produced expressed as kcal by the metabolizable energy expressed as kcal per gram of feed. Net energy for maintenance in the feed is then calculated by dividing the grams of feed that are needed to provide the kcal in the previously defined heat production into 77 kcal. An example of this procedure as determined by Lofgreen and Garrett (1968) follows.

Energy intake and heat production were found to be equal at 131 kcal of metabolizable energy intake. This value was determined from plotting heat produced per kg of metabolic body weight versus metabolizable energy intake in kcal per kg of metabolic body weight. The metabolizable energy value of this diet was 2.04 kcal per gram. By dividing the 131 kcal of metabolizable energy by 2.04 kcal per gram of feed, it is found that it requires an intake of 64.2 g of this feed per kg of metabolic body weight to produce the energy required for maintenance. The energy required for maintenance was established as 77 kcal per kg of metabolic body weight. The net energy for maintenance for this ration is equal to 77 kcal divided by 64.2 or 1.20 kcal per gram (1.20 Mcal per kg).

Net energy for production is determined by the difference in energy retention divided by the difference in feed intake at two levels of feeding. The difference in energy retention is determined by the comparative slaughter technique previously described. The retention

values are expressed as kcal retained per kg of metabolic weight. The feed intake values are expressed as grams of feed intake per kg of metabolic weight. The net energy for production in the feed is then expressed as kcal per gram. An illustration of such a determination (Lofgreen and Garrett, 1968) is listed below:

Level of feeding	Feed intake g per W ^{0.75} kg	Energy gain kcal per W ^{0.75} kg
<u>Ad libitum</u>	146	41
Equilibrium	<u>64</u>	<u>0</u>
Difference	82	41

NEg = 41/82 or 0.5 kcal/g

EXPERIMENTAL PROCEDURE

The present study involved two experiments that were designed to determine the digestibility and energy efficiency of feedlot diets containing high levels of sorghum grain.

Experiment 1

This experiment was designed to determine the digestibility of dietary components of bird-resistant sorghum grain rations with and without added bentonite or soft phosphate.

Six crossbred Hereford X Angus steers that averaged 379 kg body weight were randomly assigned to dietary treatments using a 3 X 3 crossover Latin square design, as shown in Table 1. The treatments were diets that contained bird-resistant sorghum grain (BR), BR plus 2% bentonite, and BR plus 1% soft phosphate. A detailed tabulation of the composition of the diets is presented in Table 2. The steers were adjusted to the diets during a 14-day period. During the first eight days of adjustment the steers were fed in stalls ad libitum to determine voluntary feed intake. The amount of feed offered to the steers was then decreased to 85% of each steer's voluntary feed intake and they were kept in the stalls two more days. At the end of the above ten-day period the steers were moved to metabolism racks where they were allowed to adjust to the racks and the diets for four additional days. Feces and urine were then collected for five days, which completed a 19-day cycle.

Representative samples of diets were obtained daily and composited

TABLE 1. EXPERIMENTAL DESIGN OF METABOLISM TRIAL WITH STEERS
FED SORGHUM GRAIN DIETS CONTAINING ADDED BENTONITE
OR SOFT PHOSPHATE^a

Animal		1	2	3	4	5	6
Period	I	C	A	B	C	B	A
	II	A	C	C	B	A	B
	III	B	B	A	A	C	C

^aA is control diet.

B is 2% bentonite diet.

C is 1% soft phosphate diet.

TABLE 2. INGREDIENTS OF SORGHUM GRAIN DIETS WITH ADDED BENTONITE OR SOFT PHOSPHATE FED TO STEERS DURING METABOLISM TRIAL, AS FED BASIS

	Control	2% Bentonite	1% Soft Phosphate
Ingredients	g	g	g
Bird-resistant sorghum grain	78.30	76.30	77.85
Soybean meal, 49% protein	8.00	8.00	8.00
Hay, Coastal Bermuda	10.00	10.00	10.00
Molasses, Cane	2.00	2.00	2.00
Defluorinated phosphate	1.10	1.10	0.55
Iodized salt	0.50	0.50	0.50
Trace mineral ^a	0.10	0.10	0.10
Vitamins ^b	----	----	----
Bentonite	0.00	2.00	0.00
Soft phosphate	0.00	0.00	1.00

^aTrace mineralized salt contained 250 mg manganese, 100 mg iron, 50 mg sulfate sulfur, 33 mg copper, 15 mg cobalt, 8 mg zinc and 7 mg iodine per gram.

^bVitamin concentrate added at 4.5g/453.51 kg which provides 2,200 IU/kg of feed of vitamin A and 500 IU/kg of feed of vitamin D.

at the end of the feces and urine collection period. Feces were collected twice daily and stored in metal cans with plastic liners and lids. After mixing each day's excreta, 10% of the material was frozen in plastic bags for later analysis. Urine was collected in plastic pails containing 150 ml dilute hydrochloric acid (1:4) and 10 ml of toluene as preservatives. Ten percent of each day's urine was saved and composited during the five-day collection period.

The frozen fecal samples were thawed overnight, composited, thoroughly mixed, dried at 60° C in a forced air oven for 72 hours, and then equilibrated with atmospheric moisture for 48 hours. Following this all samples were ground through a 30 mesh screen in a Wiley mill.

The diets and feces were analyzed for proximate analysis constituents, energy, and tannin content. Urine was analyzed for nitrogen, energy, and tannins. The proximate composition and adiabatic calorimeter energy were determined by the A.O.A.C. (1970) procedures, and the tannins were determined by the method outlined by Burns (1963). The statistical method used was least squares analysis (Harvey, 1960).

Composition of the diets on a dry matter basis is shown in Table 3. All diets were quite similar in proximate analysis, energy, and tannin values.

Experiment II

This experiment was designed to determine net energy for maintenance and net energy for gain values for sorghum grain diets using the California net energy procedure which includes a metabolism and feedlot study.

In a 3 X 3 Latin square design study, three Angus steers that averaged 285 kg of body weight were randomly assigned to dietary treatments as presented in Table 4. The three treatments were diets

TABLE 3. COMPOSITION OF SORGHUM GRAIN DIETS CONTAINING ADDED BENTONITE OR SOFT PHOSPHATE FED TO STEERS DURING METABOLISM TRIAL, DRY MATTER BASIS^a

	Control	2% Bentonite	1% Soft Phosphate
Ash, %	4.53	6.16	4.99
Ether extract, %	1.20	1.56	1.12
Protein, %	12.84	12.75	12.61
Fiber, %	5.54	5.59	5.57
NFE, % ^b	75.89	73.94	75.71
Energy, kcal/g ^c	4.26	4.17	4.23
Tannins, %	1.66	1.45	1.45
^a Moisture, % as fed basis	15.12	14.18	14.89

^bNitrogen-free-extract.

^cDetermined with adiabatic calorimeter.

TABLE 4. EXPERIMENTAL DESIGN OF METABOLISM PHASE OF NET ENERGY STUDY WITH STEERS FED CORN, NON-BIRD-RESISTANT, OR BIRD-RESISTANT SORGHUM GRAIN DIETS^a

Animal		03	28	35
Period	I	BR	Corn	NBR
	II	Corn	NBR	BR
	III	NBR	BR	Corn

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

that contained either high quantities of corn, non-bird-resistant sorghum grain (NDR) or bird-resistant sorghum grain (BR). A detailed description of the diets is presented in Table 5. Handling of the cattle, feed, feces and urine was exactly the same as that described in experimental procedure 1 above.

In the feedlot part of the study, 54 crossbred, Hereford and Angus steers that averaged 326 kg of body weight were randomly assigned to six dietary treatments, as shown in Table 6. All steers received feed ad libitum for ten days at which time one steer was randomly selected from each treatment group to be slaughtered and provide energy data for the steers at the start of the feeding period.

The remaining steers were shrunk for a period of 12 hours prior to the start of the feeding trial, individually weighed, implanted with 36 mg of diethylstilbestrol and started on their feeding program. Steers in the three dietary groups allowed only the restricted intake of feeds were fed to gain an average of 0.68 kg per head daily. This rate of gain figure was calculated and regulated according to their body weight and the expected gain data published by NRC bulletin (1970). The other three corresponding groups of steers were fed their diets ad libitum. Steers were weighed by groups every 28 days in order that feeding levels for restricted fed groups could be determined and readjusted if necessary. At the end of the feeding period, all animals were again shrunk 12 hours, individually weighed and transported to Gainesville, Florida, for slaughter. All animals were slaughtered and the carcasses chilled according to accepted research procedures.

Specific gravity was determined on each carcass by hydrostatic weighing of each chilled right quarter (Kraybill, Bitter and Hankins, 1952) and using the formula:

TABLE 5. INGREDIENTS OF CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS FED TO STEERS IN METABOLISM AND FEEDLOT PHASES OF NET ENERGY DETERMINATION, AS FED BASIS^a

	Corn	NBR	BR
Ingredients	g	g	g
Corn	61.00	0.00	0.00
Non-bird-resistant sorghum grain	0.00	61.00	0.00
Bird-resistant sorghum grain	0.00	0.00	61.00
Forage sorghum silage	35.00	35.00	35.00
Soybean oil meal, 44% protein	3.04	3.04	3.04
Urea (45% N)	.2872	.2872	.2872
Defluorinated phosphate	.4416	.4416	.4416
Trace mineralized salt ^b	.2208	.2208	.2208
Perma Dual 30A ^c	.0048	.0048	.0048
Baciferm 40 ^d	.0056	.0056	.0056

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^bTrace mineralized salt contained 97.5% NaCl, 250 mg manganese, 100 mg iron, 50 mg sulfate sulfur, 33 mg copper, 15 mg cobalt, 8 mg zinc, and 7 mg iodine per gram.

^cPerma Dual 30A contained 30,000 IU of vitamin A per gram.

^dBaciferm 40 contained 90 mg of zinc bacitracin per gram.

TABLE 6. EXPERIMENTAL DESIGN OF CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETARY TREATMENTS FOR STEERS DURING FEEDLOT PHASE OF NET ENERGY STUDY^a

Diet	Corn	NBR	BR
<u>Ad libitum intake</u>			
No. of animals	9	9	9
<u>Restricted</u>			
No. of animals	9	9	9

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

$$\text{Carcass specific gravity} = \frac{\text{Right side weight in air}}{\text{Right side weight in air} - \text{right side weight in water}}$$

Weights in water were taken in a tank of 48 inches diameter X 8 feet high located in a cooler maintained at a temperature of 34 to 36° F. Care was taken to minimize weighing error by carefully placing carcasses in water to reduce trapped air and by taking scale readings immediately after the carcass was submerged. Weights in water were recorded to the nearest ounce and weights in air recorded to the nearest 0.5 pounds.

The diets and feces were analyzed for proximate analysis constituents and energy content. Urine was analyzed for nitrogen and energy by A. O. A. C. (1970) procedures. Tannins in the diets were determined by the method outlined by Burns (1963).

Composition of the diets on a dry matter basis is shown in Table 7. All diets contained similar amounts of ash and energy. The NBR diet was slightly higher in percent protein and was slightly lower in nitrogen-free-extract. The corn diet contained the highest percentage of ether extract. The BR diet had the most crude fiber and tannins. The higher crude fiber value may be related to the increased percentage of tannins which form a complex with the fiber portion (VanSoest, 1969).

TABLE 7. COMPOSITION OF CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS FED TO STEERS IN METABOLISM AND FEEDLOT PHASES OF NET ENERGY DETERMINATION, DRY MATTER BASIS^{a,b}

	Corn	NBR	BR
Ash, %	3.07	3.46	3.33
Ether extract, %	4.14	2.55	2.51
Protein, %	12.71	13.67	12.34
Fiber, %	5.57	6.66	7.28
NFE, % ^c	74.51	73.66	74.55
Energy, kcal/g ^d	4.40	4.46	4.46
Tannins, %	0.51	0.94	2.15
^a Moisture as fed basis, %	37.17	37.40	36.91

^bCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^cNitrogen-free-extract.

^dDetermined with adiabatic calorimeter.

RESULTS AND DISCUSSION

Experiment 1

The addition of 2% bentonite or 1% soft phosphate to the sorghum grain diet had no significant effect on the digestion of dry matter, organic matter, fiber, nitrogen-free-extract and total digestible nutrients (Table 8). The slight decrease in dry matter and organic matter digestion when 2% bentonite was added to the diet agrees with results reported by Martin, Clifford and Tillman (1969). When 2% bentonite was added to the control diet, it decreased ($P < .01$) apparent ash absorption. Since the bentonite diet contained more ash than the other diets it appears that the ash portion contributed by the bentonite is not digestible thus lowering the overall apparent ash absorption of the diet. Soft phosphate had no significant effect on apparent ash absorption. Nitrogen digestion was reduced ($P < .01$) when bentonite was added to the sorghum grain diet while the addition of soft phosphate had no effect. However, Martin, Clifford and Tillman (1969) observed no difference in nitrogen digestion when 2% bentonite was added to sorghum grain diets. These authors fed a non-bird-resistant sorghum grain diet while cattle in this experiment were fed a bird-resistant sorghum grain diet. Soft phosphate added at 1% of the diet decreased fat digestion ($P < .05$) in comparison to the diets with and without added bentonite. The decreased fat digestion may have been due to the higher calcium content of the soft phosphate diet.

There were no significant differences in the percentage of tannins in

TABLE 8. PERCENT DIGESTION OF DRY MATTER, ORGANIC MATTER, ETHER EXTRACT, FIBER, NITROGEN, NITROGEN-FREE-EXTRACT, APPARENT ASH ABSORPTION AND TOTAL DIGESTIBLE NUTRIENTS IN METABOLISM TRIAL WITH SORGHUM GRAIN DIETS CONTAINING ADDED BENTONITE OR SOFT PHOSPHATE^{a,b,c,d}

	Control	2% Bentonite	1% Soft Phosphate
Dry matter, %	62.13	57.12	62.98
Organic matter, %	63.36	60.05	64.53
Ash, %	35.77 ^a	10.77 ^b	29.10 ^a
Ether extract, %	10.97 ^c	38.15 ^c	-6.32 ^d
Fiber, %	60.29	54.04	55.42
Nitrogen, %	40.83 ^a	30.37 ^b	42.15 ^a
NFE, % ^e	68.84	65.85	70.10
TDN, % ^f	62.75	57.59	62.97

^{a,b}Values within rows differing with superscripts a and b are significant at $P < .01$.

^{c,d}Values within rows differing with superscripts c and d are significant at $P < .05$.

^eNitrogen-free-extract.

^fTotal digestible nutrients.

the feces or urine, nitrogen retention, energy digested, or metabolizable energy when 2% bentonite or 1% soft phosphate was added to the control diet (Table 9). Steers fed the diet with 2% added bentonite excreted 76.76% of the dietary tannins, in comparison to cattle fed the control diet and soft phosphate diet which excreted 75.49 and 64.83% of the dietary tannins, respectively.

Addition of bentonite decreased slightly the amount of nitrogen retained while Martin, Clifford and Tillman (1969) observed that the addition of 2% bentonite slightly increased nitrogen retention. Neither experiment demonstrated a statistically significant effect.

Additions of 2% bentonite or 1% soft phosphate had no significant effect on energy digestion or determined metabolizable energy. When metabolizable energy was calculated from total digestible nutrients as outlined by the NRC (1970), the average difference in the calculated values and the determined values was only 5.45%. This comparison supports the calculation of metabolizable energy from total digestible nutrients by the NRC method if a determined metabolizable energy cannot be obtained.

In conclusion, the addition of 2% bentonite or 1% soft phosphate did not enhance the digestion of dry matter, total digestible nutrients, energy, or the metabolizable energy and nitrogen retention of the bird-resistant sorghum grain diet.

Experiment 11

Steers fed the corn diet digested more ($P < .05$) dry matter, organic matter, nitrogen and nitrogen-free-extract than cattle fed either the non-bird-resistant or the bird-resistant sorghum grain diet (Table 10). Digestibility of ether extract, fiber, nitrogen

TABLE 9. PERCENT TANNINS IN FECES AND URINE, NITROGEN RETENTION, PERCENT ENERGY DIGESTED, DETERMINED METABOLIZABLE ENERGY AND CALCULATED METABOLIZABLE ENERGY FROM METABOLISM TRIAL WITH SORGHUM GRAIN DIETS CONTAINING ADDED BENTONITE AND SOFT PHOSPHATE FED STEERS^a

	Control	2% Bentonite	1% Soft Phosphate
Tannins in feces/intake, %	62.41	61.43	53.81
Tannins in urine/intake, %	13.08	15.31	11.01
Nitrogen retention, g/day	8.22	-4.65	3.59
Energy digested, %	58.63	54.48	59.90
Metabolizable energy, Mcal/kg	2.14	1.95	2.20
Metabolizable energy, Mcal/kg ^b	2.27	2.08	2.28

^aValues within rows that differ in superscript a and b are significantly different at $P < .05$; none of the items tested were significantly different.

^bCalculated metabolizable energy was derived by multiplying total digestible nutrients times 3.6155 Mcal/kg (NRC, 1970).

TABLE 10. PERCENT DIGESTION OF DRY MATTER, ORGANIC MATTER, ETHER EXTRACT, FIBER, NITROGEN, NITROGEN-FREE-EXTRACT, NITROGEN RETENTION OR APPARENT ASH ABSORPTION IN CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS FED STEERS DURING METABOLISM PHASE OF NET ENERGY DETERMINATION^{a,b,c}

	Corn	NBR	BR
Dry matter, %	75.37 ^b	63.63 ^c	62.61 ^c
Organic matter, %	76.29 ^b	64.99 ^c	63.46 ^c
Ash, %	46.75	18.94	37.93
Ether extract, %	79.80	53.64	55.75
Fiber, %	44.45	25.43	31.47
Nitrogen, %	61.52 ^b	46.93 ^c	37.64 ^c
NFE, % ^d	80.93 ^b	72.53 ^c	70.94 ^c
Nitrogen retention, g/day	12.30	-1.86	2.01

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^{b,c}Values on the same line bearing different superscripts differ significantly ($P < .05$).

^dNFE is nitrogen-free-extract.

retention, and apparent absorption of ash were not significantly different in the three diets. A trend of lower digestibility of the bird-resistant sorghum grain follows the trends of reported values in the literature (Fox et al., 1970; Newland, Klosterman and Fox, 1970; and Hinders and Eng, 1971).

The corn diet contained more ($P < .05$) digestible energy and total digestible nutrients than either the non-bird-resistant or bird-resistant sorghum grain diet (Table 11). There were no significant differences between the two types of sorghum grain diets. Metabolizable energy in the corn diet was higher ($P < .01$) than either grain sorghum diet. From these data it can be concluded that the digestibility of non-bird-resistant and bird-resistant sorghum grain diets is lower for feedlot cattle than the digestibility of the corn diet.

Since metabolizable energy values for diets are not always reported, they are calculated by multiplying the percentage of total digestible nutrients times 3.6155 which gives the metabolizable energy in terms of Mcal per kg (NRC, 1970). The metabolizable energy values calculated by this method in the present study average within 1.48% of the actual determined values (Table 11). As in experiment I this supports the use of NRC formula for calculating metabolizable energy if an actual value cannot be obtained.

Performance data for the steers during the feedlot phase of the net energy determination are presented in Table 12. Steers fed the corn diet ad libitum gained more ($P < .01$) than steers similarly fed the bird-resistant sorghum grain diet or any of the three dietary groups restricted in feed intake. The corn diet fed ad libitum did not produce gains significantly greater than the full fed non-bird-resistant sorghum grain

TABLE 11. DIGESTIBLE ENERGY, TOTAL DIGESTIBLE NUTRIENTS, DETERMINED METABOLIZABLE ENERGY AND CALCULATED METABOLIZABLE ENERGY IN CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS FED STEERS DURING METABOLISM ENERGY TRIAL PHASE OF NET ENERGY DETERMINATION^a

	Corn	NBR	BR
Digestible energy, %	74.55 ^b	63.09 ^c	59.46 ^c
TDN, % ^d	79.47 ^b	65.34 ^c	64.37 ^c
Metabolizable energy, Mcal/kg	2.84 ^e	2.40 ^f	2.29 ^f
Metabolizable energy, Mcal/kg ^g	2.87	2.36	2.33

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^{b,c}Values on the same line with different superscripts differ significantly ($P < .05$).

^dTDN is total digestible nutrients.

^{e,f}Values on the same line with different superscripts differ significantly ($P < .01$).

^gCalculated metabolizable energy was derived by multiplying total digestible nutrients times 3.6155 Mcal/kg (NRC, 1970).

TABLE 12. PERFORMANCE OF STEERS FED CORN, NON-BIRD-RESISTANT OR BIRD-RESISTANT SORGHUM GRAIN DIETS DURING FEEDLOT PHASE OF NET ENERGY DETERMINATION^a

	Corn		NBR		BR	
	re- stricted	ad <u>libitum</u>	re- stricted	ad <u>libitum</u>	re- stricted	ad <u>libitum</u>
Number of steers	8	8	8	8	8	8
Avg initial wt, kg	317	315	326	325	319	317
Avg final wt, kg	420	479	428	469	396	444
Avg daily gain, kg	0.83 ^{cd}	1.33 ^b	0.76 ^{cd}	1.16 ^{bc}	0.68 ^d	1.01 ^c
Days fed	128	128	128	128	128	128
Avg dry matter intake, kg/day	5.11	8.40	5.98	8.95	6.43	10.16
Feed per kg gain	6.16	6.31	7.98	7.62	9.41	10.03

^a Corn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^{b,c,d} Values on the same line with different superscripts differ significantly ($P < .01$).

diet. There were no significant differences in gains of steers fed the two types of sorghum grain diets. Steers restricted in their feed intake had relatively the same responses to the three diets as those full fed. That is, those fed the limited corn diet produced slightly greater gains than those fed the non-bird-resistant sorghum grain diet and those fed the bird-resistant sorghum grain diet gained at a slightly slower rate than the other two groups.

Average dry matter intake was quite similar with the steers fed the non-bird-resistant sorghum and corn diets but slightly greater for those fed the bird-resistant sorghum grain diet. Feed efficiency was best for the limited and ad libitum fed corn dietary groups, poorest for those fed the non-bird-resistant sorghum grain diet and intermediate for those fed the bird-resistant sorghum grain diet. The generally lower feed efficiency of the two types of sorghum grain diets is apparently due to the overall lower availability of the nutrient components of the diets as shown in Tables 10 and 11.

Daily heat production as related to metabolizable energy intake is shown in figure 1. These data were derived from 236 cattle (Lofgreen and Garrett, 1968). Lofgreen and Garrett (1968) stated that at zero energy intake the heat produced by cattle is within the range of 72 to 83 kcal per kg of metabolic body weight, with an average of 77 kcal. The graph line of figure 1 has its origin at 77 kcal per kg of metabolic body weight. The values for heat produced in the present study by the three experimental diets when plotted in figure 1 were in close proximity to the line obtained by Lofgreen and Garrett. Therefore, in determining the energy balance between intake and heat production, Lofgreen and Garrett's line was used. The energy balance of this line occurs at an

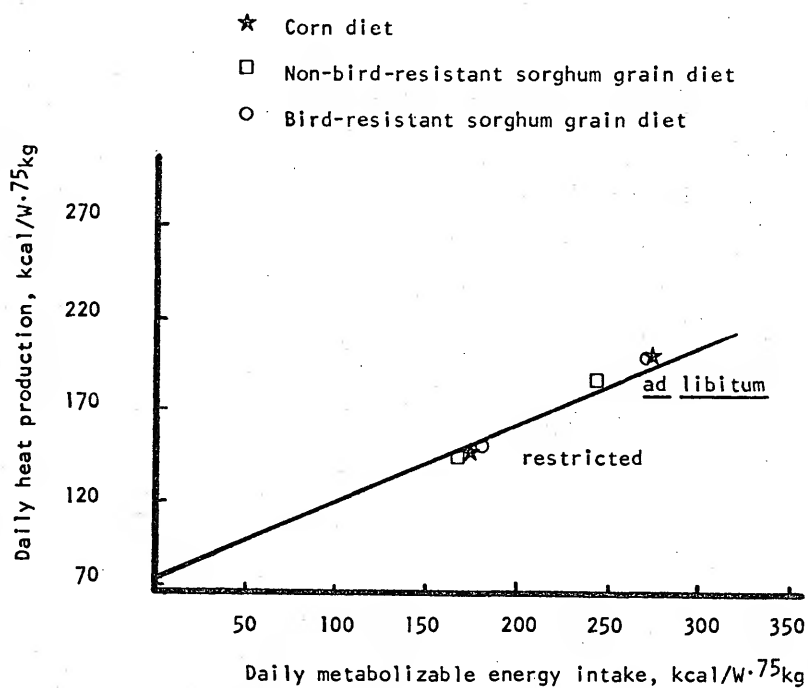


FIGURE 1. VALUES OBTAINED IN THE PRESENT STUDY
 PLOTTED ALONGSIDE THE GRAPHIC LINE PUBLISHED BY
 LOFGREEN AND GARRETT (1968)

intake of 131 kcal of metabolizable energy per kg of metabolic body weight (Lofgreen and Garrett, 1968).

Empty body weight gains and composition of empty body weight gain values used to calculate the net energy for gain values are presented in Table 13. The corn diet produced more empty body weight gain than the sorghum diets when full fed cattle are compared. The same relative gains were made with the three diets when they were restricted. The corn and non-bird-resistant sorghum grain diets produced somewhat higher percentages of fat than the bird-resistant sorghum grain diets both with the full fed and restricted cattle. Since these values are based on the mean of six animals for initial body composition, there is no statistical evaluation of the variations in treatment groups. The percentage of protein was approximately 3-4% higher in the limited fed dietary groups than in those full fed the diets. Only moderate differences in percentage of protein occurred due to the dietary treatments.

Energy required for maintenance was calculated by multiplying metabolic body weight in kg times .077. This gave a net energy for maintenance value in Mcal. Energy retained per day was determined by formulas from Lofgreen and Garrett (1968) and show cattle receiving the corn diet ad libitum retained the most energy. This also occurred when the corn diet was restricted. Total net energy is the sum of the energy required for maintenance per day plus the daily energy gain. The net energy values were determined according to the procedure of Fox et al. (1970) in which one divides the total net energy by the daily dry matter intake. These authors reported values of 1.29 for a corn grain and mixed hay diet and .94 for a bird-resistant sorghum grain and mixed hay diet.

TABLE 13. NET ENERGY FOR MAINTENANCE AND NET ENERGY FOR GAIN VALUES FOR CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS^a

	Corn				NBR			BR	
	restricted ad libitum				restricted ad libitum			restricted ad libitum	
Avg empty body weight gain, kg	104	149	89	128	80	109			
Composition of gain									
Fat, %	19.12	35.61	15.40	37.66	8.19	30.07			
Protein, %	18.62	15.30	19.03	14.65	20.59	16.58			
Avg metabolic weight, W ^{.75} kg	84.1	88.9	85.5	88.9	82.2	86.8			
Energy required for maintenance, Mcal/day ^b	6.476	6.845	6.584	6.845	6.329	6.684			
Energy gain, Mcal/day	2.315	4.895	1.749	4.365	1.214	3.212			
Total net energy, Mcal/day	8.791	11.740	8.333	11.210	7.543	9.896			
Net energy, Mcal/kg DM ^c	1.72	1.40	1.39	1.25	1.17	0.97			
NE _m , Mcal/kg ration DM	1.67	1.67	1.41	1.41	1.35	1.35			
NE _g , Mcal/kg ration DM	.82	.82	.93	.93	.57	.57			

^aCorn is corn diet. NBR is non-bird-resistant sorghum grain diet. BR is bird-resistant sorghum grain diet.

^bEnergy required for maintenance is determined by multiplying .077 times kg of metabolic body weight.

^cNet energy is determined as outlined by Fox et al. (1970) which is the sum of energy for maintenance plus energy gain divided by dry matter intake.

These values are similar to the values determined for the corn and bird-resistant sorghum grain diet fed in the present study.

In the application of net energy in the present study by the manner used by Fox et al. (1970) it was apparent that it is not constant for level of intake. The restricted level of intake in all three diets produced higher net energy values than did the ad libitum level of intake. Another limitation of the net energy values as calculated by Fox et al. (1970) is that there is no procedure for predicting gains.

Following Lofgreen and Garretts (1968) procedure for determining net energy for maintenance (NEm), the corn diet produced the highest value. The non-bird-resistant diet was slightly greater in net energy for maintenance than the bird-resistant sorghum grain diet. The maintenance values determined for these diets are somewhat lower than those reported in the NRC bulletin (1970) for the combination of dietary ingredients. The non-bird-resistant sorghum grain diet had a net energy for gain (NEg) value of .93 compared to .82 Mcal per kg of ration dry matter in the corn diet. The corresponding bird-resistant diet had a net energy for gain value of .57 Mcal per kg of ration. Net energy for gain values for the corn and bird-resistant sorghum grain diets are lower than reported in the NRC bulletin (1970) as calculated on an individual ingredient basis. The value for the non-bird-resistant sorghum grain diet is slightly higher than reported values. Due to the large difference in the two types of sorghum grain diets it is apparent that additional studies such as the present one should be made on the new varieties and types of sorghum grains.

In addition to the net energy system (NRC, 1970) used above for evaluating gains in cattle, there is the one proposed by Blaxter (1962)

based on the metabolizable energy values determined for the rations. Table 14 presents values for actual gains of steers in the present study compared to values that would be predicted by the metabolism and feedlot data using both systems for predicting gain. The two systems are quite close in predicting gains on the corn diet fed ad libitum; however, the Blaxter system is closer to the actual values with the bird-resistant sorghum grain diets, and the NRC system is closer with the non-bird-resistant diets. The NRC system was consistently closer to the actual values with all limited fed dietary groups. From the overall data the NRC system probably should be considered to be the better of the two systems. Obviously more investigation is needed to evaluate the two systems with limited steers.

In conclusion, the corn diet contains more digestible nutrients and produces faster gains with less feed intake than either sorghum grain diet. The non-bird-resistant sorghum grain diet was slightly superior for feedlot cattle in producing rate of gain than the bird-resistant sorghum grain diet.

TABLE 14. ACTUAL COMPARED TO PREDICTED BODY WEIGHT GAINS CALCULATED WITH BLAXTER'S METABOLIZABLE ENERGY EQUATIONS AND THE NRC ENERGY FOR MAINTENANCE AND GAIN VALUES OF STEERS FED CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS^{a,b,c}

	Corn		NBR		BR	
	re- stricted	<u>ad</u> <u>libitum</u>	re- stricted	<u>ad</u> <u>libitum</u>	re- stricted	<u>ad</u> <u>libitum</u>
Actual gain, kg/day	0.83	1.33	0.76	1.16	0.68	1.01
Predicted gains						
Blaxter's system, kg/day	0.51	1.26	0.37	0.84	0.45	0.92
NRC values, kg/day	0.67	1.43	0.60	1.20	0.77	1.46

^aCorn is corn diet.

NBR is non-bird-resistant sorghum grain diet.

BR is bird-resistant sorghum grain diet.

^bBlaxter's metabolizable energy equations were published by Blaxter (1962).

^cNRC gain values were derived from information given in the NRC bulletin (1970).

SUMMARY

Six crossbred Hereford X Angus steers were randomly assigned to a 3 X 3 crossover Latin square designed metabolism trial to determine the digestibility of bird-resistant sorghum grain diets with and without added bentonite or soft phosphate. The addition of 2% bentonite or 1% soft phosphate to the control diet had no significant effect on the digestion of dry matter, organic matter, fiber, nitrogen-free-extract or total digestible nutrients. Bentonite added in at 2% of the diet decreased nitrogen digestion ($P < .01$) and the addition of 1% soft phosphate decreased ether extract digestion ($P < .05$). Neither additive affected the digestion or urinary excretion of dietary tannins. Energy digestion, nitrogen retention and metabolizable energy were not affected by dietary treatments.

Fifty-seven crossbred, Hereford and Angus feedlot type steers were used to determine the net energy values of corn, non-bird-resistant and bird-resistant sorghum grain diets. Prior to the feedlot phase a metabolism trial phase with three steers in a 3 X 3 Latin square was carried out to establish metabolizable energy value for the various diets. Digestibility of other nutrients was also determined in this metabolism trial. The corn diet contained more digestible dry matter, organic matter, nitrogen, nitrogen-free-extract, energy, metabolizable energy and total digestible nutrients than either of the two types of sorghum grain diets. The non-bird-resistant sorghum grain diet contained slightly more digestible dietary components than the bird-resistant sorghum grain diet.

During the feedlot phase of the study, the corn diet produced more live weight gains on less feed than the bird-resistant sorghum grain diet. Steers fed the non-bird-resistant sorghum grain diet gained slightly faster and consumed less dry matter than steers fed the bird-resistant sorghum grain diets.

The net energy for maintenance values of the corn, non-bird-resistant and bird-resistant sorghum grain were 1.67, 1.41 and 1.35 Mcal per kg of diet, respectively. The corresponding values for net energy for gain were .82, .93 and .57 Mcal per kg of diet, respectively.

Taking all data into account the best diet for feedlot cattle was the corn diet, followed by the non-bird-resistant and finally the bird-resistant sorghum grain diet.

Metabolizable energy calculated by multiplying the NRC factor times the total digestible nutrients gave values within 5% of those actually determined. Blaxter's metabolizable energy system and the net energy for maintenance and gain values in tables from the NRC bulletin on Nutrient Requirements of Beef Cattle were compared in regard for predicting gains. Both procedures for predicting gains come within .1 kg per day of those actually observed when steers were fed the corn diet ad libitum in the present study. The NRC system is closer to actual gain values for the non-bird-resistant sorghum grain diets while Blaxter's system is closer with the bird-resistant sorghum grain diet. Predicted gains for steers in the limited dietary intake treatments were much closer using the NRC tables than Blaxter's system.

APPENDIX

TABLE 15. RATE OF GAIN, DRY MATTER CONSUMPTION AND FEED EFFICIENCY DETERMINED FROM CATTLE FED CORN, NON-BIRD-RESISTANT OR BIRD-RESISTANT SORGHUM GRAIN DIETS DURING FEEDLOT PHASE OF NET ENERGY DETERMINATION^a

Item	Time In days	Corn restricted	NBR restricted	BR restricted	Corn ad libitum	NBR ad libitum	BR ad libitum
Average daily gain, kg	0- 28	0.49	0.61	0.48	1.57	1.22	1.21
	28- 56	1.34	0.97	0.83	1.69	1.47	1.51
	56- 84	0.79	1.04	0.91	1.26	1.21	0.84
	84-112	0.47	0.61	0.35	1.01	0.76	0.77
	112-128	1.26	0.46	0.96	0.96	1.15	0.53
	0-128	0.83	0.76	0.68	1.33	1.16	1.01
Total feed consumption, kg	0- 28	1137	1307	1318	1720	1774	1938
	28- 56	1274	1388	1554	1858	2070	2451
	56- 84	1195	1427	1444	2025	2170	2564
	84-112	1040	1274	1405	1973	2067	2333
	112-128	591	725	864	1030	1090	1116
	0-128	5237	6121	6585	8606	9171	10420

TABLE 15. continued

Item	Time in days	Corn restricted	NBR restricted	BR restricted	Corn ad libitum	NBR ad libitum	BR ad libitum
Feed efficiency, kg./feed/kg gain	0- 28	10.27	9.61	12.26	4.88	6.51	7.19
	28- 56	4.22	6.38	8.35	4.91	6.25	7.26
	56- 84	6.76	6.11	7.07	7.39	8.04	13.85
	84-112	9.96	9.59	17.78	8.70	12.15	13.54
	112-128	3.82	12.30	7.05	8.38	7.40	16.34
	0-128	6.16	7.98	9.41	6.31	7.62	10.03

^aCorn is corn diet.

NBR is non-blrd-resistant sorghum grain diet.

BR is blrd-resistant sorghum grain diet.

TABLE 16. CARCASS SPECIFIC GRAVITY, BODY SPECIFIC GRAVITY, BODY WATER, BODY FAT, AND BODY PROTEIN DETERMINED FROM STEERS FED CORN, NON-BIRD-RESISTANT AND BIRD-RESISTANT SORGHUM GRAIN DIETS DURING NET ENERGY STUDY^a

Lot	Animal brand no.	Animal slaughter no.	Carcass specific gravity	Body specific gravity	Body water %	Body fat %	Body protein %
Control	04		1.0455	1.0394	52.53	25.52	17.63
	112		1.0385	1.0325	50.20	28.68	16.96
	111		1.0424	1.0364	51.52	26.86	17.42
	52		1.0411	1.0351	51.08	27.45	17.30
	20		1.0563	1.0502	56.11	20.96	18.42
	559		1.0443	1.0383	52.16	26.01	17.59
Corn restricted	70	100	1.0519	1.0458	54.66	22.76	18.14
	92	101	1.0516	1.0455	54.56	22.89	18.11
	72	102	1.0474	1.0413	53.16	24.69	17.79
	30	103	1.0417	1.0357	51.28	27.18	17.29
	76	104	1.0359	1.0299	49.31	29.94	16.62
	06	105	1.0615	1.0554	57.81	18.93	18.68
	41	106	1.0568	1.0507	56.27	20.79	18.42
	66	107	1.0504	1.0443	54.16	23.40	18.02

TABLE 16. continued

Lot	Animal brand no.	Animal slaughter no.	Carcass specific gravity	Body specific gravity	Body water %	Body fat %	Body protein %
Non-bird- resistant restricted	36	99	1.0450	1.0359	52.36	25.75	17.58
	107	116	1.0593	1.0532	57.09	19.78	18.58
	555	117	1.0459	1.0398	52.66	25.34	17.72
	40	118	1.0570	1.0509	56.34	20.69	18.45
	106	119	1.0423	1.0363	51.49	26.89	17.36
	12	120	1.0606	1.0545	57.51	19.27	18.65
	65	122	1.0500	1.0349	54.03	23.57	17.99
	18	123	1.0453	1.0392	52.46	25.61	17.61
	560	124	1.0406	1.0399	52.69	25.31	17.67
	62	125	1.0542	1.0481	55.42	21.81	18.29
Bird-resistant restricted	82	126	1.0599	1.0538	57.29	19.54	18.61
	49	127	1.0589	1.0528	56.96	19.93	18.56
	86	128	1.0464	1.0403	52.83	25.14	17.69
	105	129	1.0621	1.0560	58.00	18.71	18.71
	549	130	1.0545	1.0484	55.52	21.68	18.31
	564	131	1.0578	1.0517	56.60	20.38	18.54

TABLE 16. continued

Lot	Animal brand no.	slaughter no.	Carcass specific gravity	Body specific gravity	Body water %	Body fat %	Body protein %
	79	140	1.0386	1.0326	50.23	28.63	16.98
	553	141	1.0277	1.0217	46.49	34.10	15.59
	561	142	1.0422	1.0362	51.45	26.96	17.39
Corn ad libitum	08	143	1.0324	1.0264	48.12	31.65	16.25
	99	144	1.0264	1.0204	46.04	34.76	15.42
	50	145	1.0368	1.0308	49.62	29.48	16.79
	119	146	1.0506	1.0445	54.23	23.32	18.03
	55	147	1.0419	1.0359	51.35	27.10	17.31
	26	97	1.0263	1.0203	46.01	34.81	15.40
	11	132	1.0292	1.0232	47.01	33.30	15.77
Non-bird- resistant ad libitum	21	133	1.0279	1.0219	46.56	33.96	15.65
	09	134	1.0526	1.0465	54.89	22.86	18.18
	16	135	1.0470	1.0409	53.03	24.86	17.76
	59	136	1.0325	1.0265	48.15	31.62	16.25
	46	138	1.0434	1.0374	51.86	25.41	17.45
	53	139	1.0304	1.0244	47.43	32.66	15.99

TABLE 16. continued

Lot	Animal brand no.	slaughter no.	Carcass specific gravity	Body specific gravity	Body water	Body fat	Body protein
					%	%	%
	96	108	1.0427	1.0367	51.62	26.73	17.39
	07	109	1.0316	1.0256	47.84	32.06	16.14
Bird-resistant	19	110	1.0418	1.0358	51.32	27.13	17.31
<u>ad libitum</u>	22	111	1.0439	1.0379	52.02	26.19	17.50
	83	112	1.0390	1.0330	50.37	28.32	17.12
	117	113	1.0534	1.0473	55.15	22.14	18.24
	101	114	1.0290	1.0230	46.94	33.39	15.80
	75	115	1.0527	1.0466	54.92	22.43	18.19

^aCarcass specific gravity was determined but all other values were calculated as outlined according to Lofgreen and Garrett (1968).

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BIOGRAPHICAL SKETCH

William Edwin Maxson was born in Turlock, California, on October 4, 1947. His family moved to Delano, California soon afterward, where he attended public school and graduated from Delano High School in 1965. Next he was accepted by California State Polytechnic College where he majored in Animal Husbandry and graduated with the degree of Bachelor of Science in Agriculture in June of 1969. While in attendance at California State Polytechnic College the author served as President of Boots and Spurs as well as the Collegiate 4-H Club. In September, 1969, he entered graduate school at the University of Florida where he graduated with the degree of Master of Science in Agriculture in August, 1971. He continued his education at the University of Florida where he is now a candidate for the degree of Doctor of Philosophy in Animal Science.

William Edwin Maxson is a member of Gamma Sigma Delta, the Honor Society of Agriculture, and the Society of Sigma Xi. He married Joann Lee Pederson of Los Altos, California, in August, 1969.

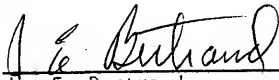
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Ray L. Shirley, Chairman
Professor of Animal Nutrition

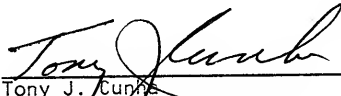
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Clarence B. Ammerman
Professor of Animal Nutrition

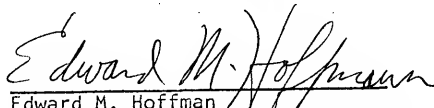
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Joe E. Bertrand
Associate Professor of Animal Science

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Tony J. Cunningham
Professor of Animal Science

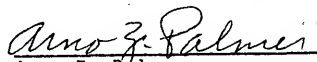
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Edward M. Hoffman
Associate Professor of Microbiology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

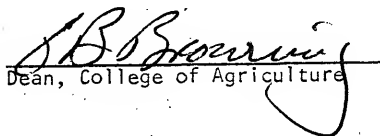

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


Arno Z. Palmer
Professor of Meat Science

This dissertation was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

March, 1973


Dean, College of Agriculture

Dean, Graduate School